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GACIAC SR 88-10

CONFERENCE ON SPACE AND MILITARY APPLICATIONS OF AUTOMATION AND ROBOTICS

21-22 JUNE 1988

PROGRAM & TECHNICAL PAPER ABSTRACTS

NASA

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Huntsville, Alabama 35898-5243

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A record of this conference will be published in the form of The Proceedings of the Conference on Space and Military Applications of Automation and Robotics, GACIAC PR-88-02. The proceedings will contain all of the papers presented at the conference, and will be available to all those attending the conference. Government contractor personnel should send a check or purchase order in the amount of $75.00 payable to: IIT Research Institute/GACIAC, 10 West 35th Street, Chicago, Illinois 60616-3799. GACIAC products are available to government/military personnel at no cost, if requested on official government stationery.

GACIAC SR 88-10 JUNE 1988

CONFERENCE ON SPACE AND MILITARY APPLICATIONS OF AUTOMATION AND ROBOTICS

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PROGRAM AND TECHNICAL PAPER ABSTRACTS

CONDUCTED AT THE
MARRIOTT OF HUNTSVILLE
5 TRANQUILITY BASE
HUNTSVILLE, ALABAMA 35805

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Marshall Space Flight Center, Alabama 35812

CONFERENCE ON SPACE AND MILITARY APPLICATIONS OF AUTOMATION AND ROBOTICS

21-22 JUNE 1988

MARRIOTT OF HUNTSVILLE, ALABAMA

Technical Program Chairman:	Dr. Gary L. Workman University of Alabama in Huntsville
General Chair:	Elaine Hinman NASA/MSFC
	J. L. Prater USAMICOM/RDEC
Plenary Session:	Elaine Hinman NASA/MSFC
	J. L. Prater USAMICOM/RDEC
Welcoming Remarks:	J. R. Thompson, Director NASA/MSFC
	W. C. McCorkle, Director USAMICOM/RDEC
NASA Keynote:	J. B. Odom Associate Administrator for the Space Station NASA Headquarters
Army Keynote:	J. D. Weisz, Director Human Engineering Laboratories LABCOM
Plenary Presentation:	Steve Bartholet Odetics, Inc.

Monday, June 20, 1988

06:00 - 08:00 PM **Pre-Registration in Marriott Lobby Area**

Tuesday, June 21, 1988

07:30 - 08:30 AM **Registration (lobby)**

08:00 - 10:00	**Plenary Session I** Chairs: Elaine Hinman, NASA/MSFC J.L. Prater, USAMICOM/RDEC
08:05	**Welcoming Remarks:** J.R. Thompson, Director, NASA/MSFC W.C. McCorkle, Director, USAMICOM/RDEC
08:25	**NASA Keynote:** J.B. Odom, Associate Administrator for the Space Station NASA HQ
08:55	**Army Keynote:** J.D. Weisz, Director, Human Engineering Laboratories LABCOM
09:35	**Plenary Presentation:** Steve Bartholet, Odetics, Inc.
10:15	**BREAK**
10:30	**Session II Program A** **IVA Robotics** **Chair: Pam Nelson, NASA/MSFC**
Keynote:	**W.B. Chubb, Director, Information and Electronic Systems Laboratory, MSFC**
	"An Automated Protein Crystal Growth Facility on the Space Station" Melody Hermann, NASA/MSFC
	"The Impact of an IVA Robot on the Space Station Microgravity Environment" Philip Harman, Teledyne Brown Engineering
	"Dual Arm Robots for Telerobotic IVA Operations on the Space Station" Carl Ziemke, Jac Kader, and Larry Yawn/Kader Robotics, Inc.

10:30 **Session II Program B**
Strategies for Deployment
Chair: J.L. Prater, USAMICOM/RDEC

Keynote: **Colonel J.D. Petty, Director**
Advanced System Concepts Office

"TMAP - The Army's Near-Term Entree to Battlefield Robotics"
Richard Simmons, Martin-Marietta Baltimore

"When Will Robots Be Used in Combat?"
Scott Harmon, Robot Intelligence International

"TMAP: An Offset System"
Jerry Kirsch, Grumman Corporation

12:00 **LUNCH (served poolside)**

01:30 **Session III Program A**
Artificial Intelligence and Expert Systems I
Chair: Elaine Hinman, NASA/MSFC

"An Expert System for Object Recovery"
A. Farsaie and W.A. Venezia, Naval Surface Weapons Center

"High Level Intelligent Control of Teleoperatic Systems"
Jim McKee, University of Alabama in Huntsville, and
John Wolfsberger, NASA/MSFC

"Neutral File Data Exchange Between Simulators and Robots"
William Engelke and David Gilliam
University of Alabama in Huntsville

"Cooperating Expert Systems"
Michael Brady and D.R. Ford
University of Alabama in Huntsville

"Space Languages"
Steve Davis and Dan Hayes, University of Alabama in
Huntsville and
John Wolfsberger, NASA/MSFC

01:30 **Session III Program B**
Sensors and Image Processing
Chair: Lynn Craft, MICOM

"A System for High Resolution 3D Mapping Using Laser Radar and Requiring No Beam Scanning Mechanisms"
Paul Rademacher, Robotic Vision Systems, Inc.

"Technology Transfer: Imaging Tracker to Robotic Controller"
W. Otaguro, L.O. Kesler, Ken Land, Harry Erwin, and Don Rhoades
McDonnell Douglas Astronautics Co.

"Stabilized Image System for Mobile Robots".
David Stauffer and Edward Watts
Rexham Aerospace and Defense Group

"Two-Dimensional Convolute Integer Technology for Digital Image Processing"
Thomas Edwards, TREC, Inc.

03:15 **BREAK**

03:30 **Session IV Program A**
Robotic Systems
Chair: Chuck Shoemaker, Human Engineering Laboratory

"Development of a Hybrid Simulator for Robotic Manipulators"
Peter Van Wirt and Captain M.B. Leahy, Jr.,
Air Force Institute of Technology

"Omni-Con: The Self-Aligning Space Connector"
H.S. Harman, Environmental Components, Inc., and
Keith Clark, NASA/MSFC

"Disconnects for Spacecraft Servicing Applications"
J. M. Cardin, Moog Incorporated

"A New Approach to Robot Kinematics"
Mary S. Waggener and F.J. Testa
Advanced Control Technologies, Inc., and
Guy O. Beale, George Mason University

03:30 **Session IV Program B**
Guidance, Navigation and Control
Chair: Greg Graham, USAMICOM

"The DARPA Autonomous Land Vehicle: A Phase I Retrospective and a Prospective for the Future"
Robert Douglas, Martin-Marietta Denver

"Development of a Man-Portable Control Unit for a Teleoperated Land Vehicle"
D.E. McGovern and S.V. Spires, Sandia National Laboratories

"Robotic Visual Servo Control for Aircraft Ground Refueling"
Mikel Miller, Captain M.B. Leahy, Jr., and
Matthew Kabrisky, Air Force Institute of Technology

"Use of Mobile Robots in Responding to Radiological and Toxic Chemical Accidents"
Harvey Miereran, PHD Technologies, Inc.

"The Versatool III"
F.R. Skinner, Robo-Tech Systems

05:30 - 07:30 **Reception (Marriott Ballroom)**
Chair: G.L. Workman, University of Alabama in Huntsville

Speaker: **Joe Engelberger, TRC, Inc.**

Wednesday, June 22, 1988

08:00 AM Session V Program A
Robotic Systems
Chair: Ken Fernandez, NASA/MSFC

Keynote: J.W. Littles, Director, Science and Engineering, MSFC

"Insertion with Two Coordinated Arms"
F.L. Swern and S.J. Tricamo, Stevens Institute of Technology

"Orbital Maneuvering Vehicle (CMV) Remote Servicing Kit"
N.S. Brown, NASA/MSFC

"Inflatable End-Effector Tools"
Carter K. Lord, Olis Engineering, Inc.

08:00 AM Session V Program B
Manufacturing of Aerospace and Missile Systems I
Chair: Howard Race, USAMICOM

Keynote: R.E. Bowles, Chief of Mobility of Technology Planning and Management, LABCOM

"Robot Assembly of Microscopic Components in Millimeter Wave Devices"
Steven Prokosch, Honeywell, Inc.

"Automated Millimeter Wave Transducer Testing in a Robotic/Vision Test Cell"
Mark Francis, Honeywell, Inc.

"Development of an Integrated CAD/CAM System for Wire Harness Fabrication"
J.M. Anderson, J.I. Locker, T.D. Morgan, L.C. Frederick and C.D. Minor, University of Alabama in Huntsville

10:15 BREAK

10:30 **Session VI Program A**
Telerobotics
Chair: Cindy Coker, NASA/MSFC

"Testing the Feasibility of Using a Teleoperated Robot for Remote Dextrous Operations"
John Molino, Tech-U-Fit Corporation

"ORU Guidelines for Teleoperations Compatibility"
Margaret M. Clarke and Davoud Manouchehri, Rockwell International

"Ground Control of Space Based Robotic Systems"
Ken Farnell and S.F. Spearing, Teledyne Brown Engineering

"The Advanced Research Manipulator I"
Peter D. Spidaliere, AAI Corporation

"Investigation of Learning Factors in the Performance of Teleoperated Tasks"
Richard W. Amos

10:30 **Session VI Program B**
Manufacturing of Aerospace and Military Systems II
Chair: Chip Jones, NASA/MSFC

"A Generalized Method for Automatic Downhand and Wirefeed Control of a Welding Robot and Positioner"
Ken Fernandez, NASA/MSFC and
George E. Cook, Vanderbilt University

"On Designing a Case-Based System for Expert Process Development"
Seraj Bharwani, J.T. Walls, and M.E. Jackson
Martin Marietta Laboratories

"Expert System Technology: An Avenue to an Intelligent Weld Process Control System"
R.E. Reeves, T.D. Manley, and A. Potter
General Digital Industries, Inc., and
D.R. Ford, University of Alabama in Huntsville

"Advantages of Off-Line Programming and Simulation for Industrial Applications"
John Shiver, Martin Marietta Aerospace, and
David Gilliam and G.L. Workman, University of Alabama in Huntsville

12:00 Noon **Lunch (served poolside)**

01:30 **Session VII Program A**
Manufacturing of Aerospace and Military Systems III
Chair: J.M. Anderson, USAMICOM

"3-D Graphical Simulation of an Automated Direct Chip Probe/Test System"
Daron Holderfield, U.S.A.MICOM
T.D. Morgan, B.E. Martin, and J.R. Facemire
University of Alabama in Huntsville

"Using a Simulation Assistant in Modeling Manufacturing Systems"
B.J. Schroer, F.T. Tseng, and S.X. Zhang
University of Alabama in Huntsville

"Algorithm for Display of Automated Nondestructive Thickness Measurements"
Jeroen van der Zijp, University of Alabama in Huntsville

01:30 **Session VII Program B**
Artificial Intelligence and Expert Systems II
Chair: Bernard Schroer, University of Alabama in Huntsville

"A Robotic Vehicle Global Route Planner for the 1990's"
William Pollard, KMS Fusion, Inc.

"A Demonstration of Retro-Traverse Using a Semi-Autonomous Land Vehicle"
D. McGovern, P.R. Klarer, and D.P. Jones
Sandia National Laboratories

"Dynamic Planning for Smart Weapons"
Stanley Larimer and R.A. Luhrs, Martin-Marietta Denver

"A Knowlege Representation Scheme for a Robotic Land Vehicle Route Planner"
P.J. McNally, KMS Fusion, Inc.

"IRIS - An Intelligent Robot Insertion Expert System"
William Teoh, Sparta, Inc.

"Pedagogical Issues in Developing a Man-Machine Interface for an Intelligent Tutoring System"
Willard Holmes, USAMICOM

PLENARY SESSION I

CHAIRS: Elaine Hinman, NASA/MSFC

and

J. L. Prater, USAMICON/RDEC

WELCOMING REMARKS

J. R. Thompson, Director
NASA/MSFC

and

W. C. McCorkle, Director
USAMICOM/RDEC

James R. Thompson, Jr.
NASA HQ

Welcoming Speaker

James R. (J.R.) Thompson, Jr., was named director of the Marshall Center on September 29, 1986, after serving three years as Deputy Director (technical) at the Princeton University Plasma Physics Laboratory. In 1986, while still at Princeton, he was named vice-chairman and day-to-day head of the NASA task force looking into the cause of the Challenger accident. Before going to Princeton, Mr. Thompson spent 20 years as manager of the NASA/aerospace industry team that developed the main engine of the Space Shuttle, perhaps the most sophisticated machine ever built. He also served as Associate Director for Engineering in the Center's Science and Engineering Directorate, the organization responsible for developing many of the nation's space projects. Today, as Director of one of NASA's largest and most diversified centers, Mr. Thompson is responsible for many of the agency's top programs.

Under Mr. Thompson's leadership, the Marshall Center is responsible for a wide variety of NASA projects ranging from development of the Edwin P. Hubble Space Telescope and production of the propulsion elements of the Space Shuttle to management of Spacelab Earth-orbital missions and other payloads for the Space Shuttle. Also, the Marshall Center has been given a substantial role in the development of Space Station, a permanent manned facility proposed by President Reagan to be in orbit by the mid-1990s.

William Claiborne McCorkle, Jr.
USAMICOM/RDEC

Welcoming Speaker

As MICOM Technical Director, Dr. McCorkle serves as the senior technical advisor to the Commander on all research and development matters. As Director of the Research, Development and Engineering Center, he is responsible for providing major research, development, production, field engineering and software support to more than twenty MICOM project and product managed systems. In addition, he is responsible for planning and executing the Missile Command's programs in research, exploratory and advanced development of missiles and high energy lasers.

Dr. McCorkle came to the Missile Command in 1957 from a position at Tulane University and has since served in a number of increasingly responsible scientific and engineering positions, including an 18-month rotational assignment in the Department of Army Staff as Science Advisor to the Director of Weapons Systems. He has worked on missile-related research and development problems and projects associated with virtually every missile and rocket system under MICOM cognizance. His contributions include numerous papers and patents in guidance and control, such as the complete guidance system used in the LANCE missile, and major improvements to the HAWK missile system, including the most recent improvement permitting multiple simultaneous engagements. He has achieved national recognition for initiating and guiding the Center's highly successful pioneering work in fiber optic guidance links for missiles, providing a revolutionary new countermeasure-resistant capability for finding and engaging both rotary wing and armored targets out of the gunner's line of sight. Dr. McCorkle has long effectively championed the use of simulation techniques for missile design and analysis and initiated the effort that led to MICOM's Advanced Simulation Center, a major national facility and key to a number of successful missile development and improvement programs.

In November 1980, Dr. McCorkle was selected for the dual role of MICOM Technical Director and Director of the U.S. Army Missile Laboratory (now the Research, Development, and Engineering Center).

Dr. McCorkle holds a Ph.D. in physics from the University of Tennessee and a B.S. in physics from the University of Richmond, Virginia. He received the following awards: Outstanding Performance Awards, Army R&D Achievement Award, Meritorious Civilian Service Award, Holger N. Toftoy Award for Technical Management, (American Institute of Aeronautics and Astronautics), Hermann Oberth Award, Exceptional Civilian Service Award, Leslie E. Simon/Crozier Award (American Defense Preparedness Association), and Presidential Distinguished Executive Rank.

NASA KEYNOTE

J. B. Odom
Associate Administrator for the Space Station
NASA HQ

James B. Odom
NASA HQ

Keynote Speaker

James B. Odom, who recently assumed the duties of Associate Administrator for the Space Station, worked at Marshall Space Flight Center for more than 30 years, serving as Director of the Science and Engineering Directorate from 1986 to 1988 and prior to that, was Manager of the Hubble Space Telescope Project.

At Marshall Space Flight Center, Mr. Odom has held many engineering and management positions. He was highly involved in the development of earth satellites and unmanned space probes before his assignment as Chief of the Engineering and Test Operation Branch for the Second Stage of the Saturn Vehicle. In 1972, he was appointed Manager of the External Tank Project in the Space Shuttle Project Office. He became Manager of the Hubble Space Telescope Office in 1983.

Mr. Odom graduated from Auburn University in 1955 with a BS in Mechanical Engineering. He has received numerous NASA awards including the NASA Exceptional Service Medal in 1973 for his contributions to the Saturn S-2 stages and the NASA Distinguished Service Medal in 1981 for his work in developing the Space Shuttle and its successful first orbital test flight. In 1985, Mr. Odom was awarded the Presidential Rank of Meritorious Executive in recognition of his contributions to both the External Tank and Space Telescope Projects.

ARMY KEYNOTE

J. D. Weisz, Director
Human Engineering Laboratories,
LABCOM

John D. Weisz
Human Engineering Laboratories
LABCOM

Army Keynote Speaker

Dr. Weisz joined the Human Engineering Laboratory (HEL), Aberdeen Proving Ground, Maryland in 1953 and was appointed Director of the Laboratory in 1957. The laboratory became the U.S. Army Human Engineering Laboratory, a separate activity reporting directly to the U.S. Army Materiel Development & Readiness Command (DARCOM) in Alexandria, Virginia.

The HEL has been designated as the Lead Laboratory for Human Factors Engineering Technology within Department of the Army and DARCOM Lead Agency for Robotics and Military Operations in Urban Terrain (MOUT). The primary mission of the HEL is to assure that Army materiel evolved conforms with the capabilities and limitations of the fully equipped soldier to operate and maintain the materiel in its operational environment consistent with tactical requirements and logistic capabilities. Dr. Weisz has been very active in the area of manpower resources integration efforts in Department of Defense (DoD) materiel development programs. He served on a special DoD study in 1967 and helped write the first Army Regulation (AR 602-1) on this subject. He also served as a member of the Army Research Council which reported directly to the Assistant Secretary of the Army for Research & Development.

Dr. Weisz has authored numerous technical reports and articles in technical journals in the fields of human factors engineering, psychosomatic medicine, retardation, and experimental physiology. Dr. Weisz is also a member of the National Research Council Vision Committee and the Acoustics Committee; Sigma XI, and has served as President of the Northern MD Retarded Association (NARC) and the Maryland Association for Retarded Citizens, Inc. (MARC).

Dr. Weisz also has received a number of awards, among them are the Junior Chamber of Commerce Outstanding Young Citizen; Outstanding Performance and Superior Performance; DA Certificate of Achievement; Department of the Army Decoration for Meritorious Civilian Service and the Department of Army Decoration for Exceptional Civilian Service; Award of Merit as employer of the year for employment of the Handicapped, State of Maryland; the DoD Distinguished Civilian Service Award and received the first Leslie Simon Award presented by ADPA.

PLENARY PRESENTATION

Steve Bartholet
Odetics, Inc.

Steve Bartholet
Odetics, Inc.

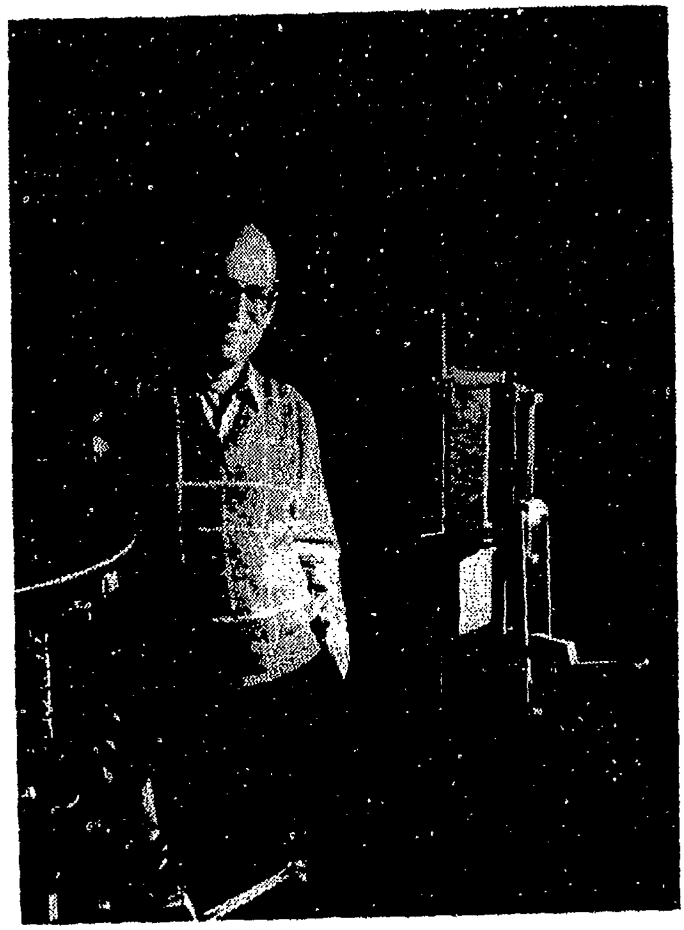
Plenary Speaker

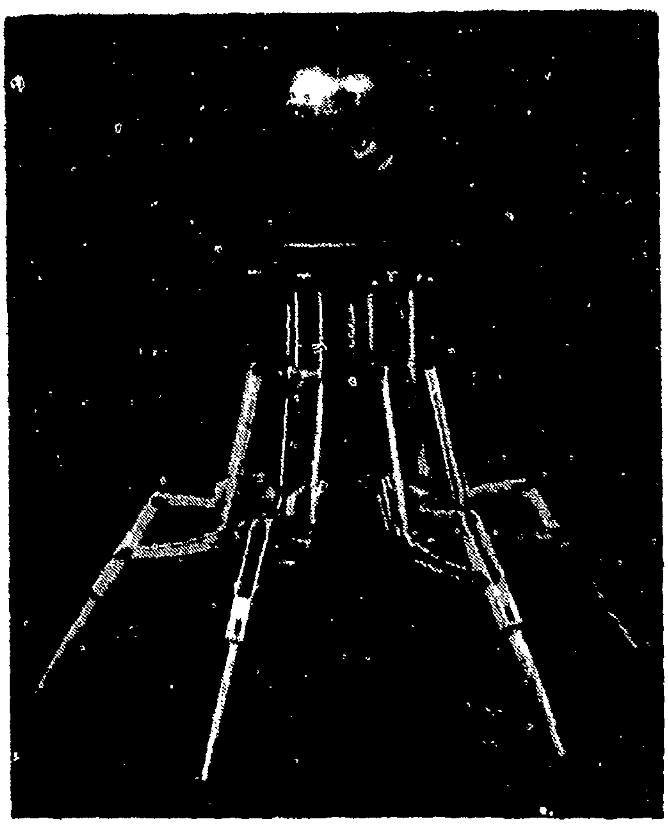
Steve Bartholet conceived and managed the construction of ODEX I, the six-legged walking robotic demonstrator for which he and Odetics, Inc. hold patents for the leg mechanisms. The Odex I was built as a technology demonstrator and resource base for future intelligent machine system developments. Each of the six legs has three degrees of freedom. The total of 18 d.o.f. must be controlled in real-time through algorithms for the 6 legs, which share overlapping work spaces.

At "Robots 11" in April 1987, he was presented the First Annual Jean Vertut Award for Excellence from Robotics International.

Force-component isolation designs were invented by Mr. Bartholet for the ODEX I legs. Each of the six legs weighs 50 pounds, including motors, gears and all sections. The lift capability of each leg is 45 pounds in any position. The computing power of the ODEX greatly simplifies the man-machine interfaces. The teleoperator deals only with high-level commands for mode of operation, selection of parameter boundaries, and driving of the body of the ODEX through a rate-control joystick. The teleoperator can similarly take control of any leg and operate it as an arm. The legs are under state-of-the-art closed-loop, continuous path trajectory management. Yet, the new advances in embedded computer control represented by the ODEX result in smooth, rapid, and continuous motion.

Steve B. photographs





THE FIRST FUNCTIONOID ODEX I

CONFERENCE ON SPACE AND MILITARY APPLICATIONS
OF AUTOMATION AND ROBOTICS

ABSTRACTS

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Session II Program A

IVA Robotics

Chair: Pam Nelson, NASA/MSFC

Keynote Speaker: W. B. Chubb, Director
Information and Electronic Systems Laboratory
MSFC

An Automated Protein Crystal Growth Facility on the Space Station

Meloay Herrmann
NASA/MSFC

ABSTRACT

This paper will address the need for an automated Protein Crystal Growth experiment on the Space Station and how robotics will be integrated into the system design. This automated laboratory system will enable several hundred protein crystals to grow simultaneously in microgravity and will allow the major variables in protein crystal growth to be monitored and controlled during the experiment. Growing good quality crystals is important in determining the complete structure of the protein by X-ray diffraction. This information is useful in the research and development of new medicines and other important medical and biotechnological products.

Previous Protein Crystal Growth Shuttle experiments indicate that the microgravity environment of space allows larger crystals of higher quality to be grown as compared to the same crystals grown on the ground. It is therefore important to have a laboratory in Space where protein crystals can be grown under carefully controlled conditions so that a crystal type can be reproduced as needed.

The Impact of an IVA Robot on the Space Station Microgravity Environment

Phillip E. Harman
Teledyne Brown Engineering
Cummings Research Park
Huntsville, AL 35807

ABSTRACT

In order to maintain a microgravity environment during Space Station operations, it will be necessary to minimize reaction forces. These mechanical forces will typically result during reboost, docking, equipment operation, IVA robot operations or crew activity. This paper will describe the impact of these accelerations on the experiments by focusing on those disturbances created by an IVA robot. An explanation of the robot dynamic analysis that was used to generate the forcing function as the input into a finite element model of the U.S. laboratory will be shown. These results will identify the acceleration levels at locations throughout the module in order to assess the impact a robotic system will have on space station operations and the microgravity environment. Results will also be shown for the disturbances created by other sources. The results will help quantify what g-level environment can be obtained on the station and the effect of an IVA robot. A comparison between IVA robot effects and crew motion effects on the low-g environment will be described.

Dual-Arm Robots for Telerobotic IVA Operations on the Space Station

M. Carl Ziemke, Jac Kader and Larry Yawn
Kader Robotics, Inc.

ABSTRACT

Sometime during the middle of the next decade, the U.S. Space Station will achieve IOC (Initial Operating Capability). The primary justification for this multi-billion dollar project is that a volume of scientific and industrial activities will take place in the various modules being designed for these purposes.

These activities will be accomplished or directed by a crew of only eight to ten members, whose work time has been estimated to cost $20,000 to $50,000 per person-hour. NASA has stated that the productivity of this initial crew must be "amplified" by extensive use of automation and robotics. But in 1985, the astronauts expressed a strong preference for vital equipment that will be 100% capable of manual operation in the event of machine failure.

Thus, much of the equipment in the Space Station will probably be designed for operation using controls adapted primarily for the human hand and arm. In many cases, these operations will require use of both hands. Therefore, if a machine normally operated by a robot requires direct human operation, it must be possible to manuever the robot out of the way to permit direct manual operation. These contraints strongly emphasize the need for dexterous, dual-arm robots for Space Station IVA.

One of the problems of operation of a dual-arm robot is the coordination of movement between both arms when they are simultaneously engaged in performing a task. Kader Robotics has produced a unique dual-arm robot design employing assymetrical manipulator arms that pivot on a common radius. The advantages of this concept in meeting NASA's IVA robot needs are described in detail. These advantages include compactness, light weight and reduced tendency toward interarm collisions.

Session II Program B

Strategies for Deployment

Chair: J. L. Prater, USAMICOM/RDEC

Keynote Speaker: Colonel J. D. Petty, Director
Advanced Systems Concepts Office

TMAP--The Army's Near Term Entre To Battlefield Robotics

Richard K. Simmons
Martin Marietta Aero & Naval Systems
Baltimore, Maryland

ABSTRACT

The TMAP System is being developed by Martin Marietta for the U.S. Army Missile Command under a Sandia National Laboratories contract. The Martin Marietta design uses state-of-the-art technology in innovative ways to give the Army a readily-fieldable, simple-to-operate battlefield surveillance/reconnaisance system. The small, lightweight TMAP system provides remotely operable eyes and ears beyond a 4 km range, day or night, in rough terrain. The Proof of Principle (POP) System will provide target designation for laser guided systems. With minor modifications TMAP can be configured for antiarmor weapons, air defense weapons, NBC detection, mine detection, medic support and equipment carrying. TMAP will be Acceptance Tested in August 1988 and will undergo evaluation tests at Ft. Benning, Georgia, in October and November 1988.

When Will Robots Be Used In Combat?

S. Y. Harmon
Robot Intelligence International
San Diego, CA 92107

ABSTRACT

Considerable interest in applying automation to various areas of the operational military has developed recently as a result of the increasing cost of battle and the increasing sophistication and numbers of the potential threat. This paper explores the question "when will robots be used in combat?", a rigorous analysis of the advantages of battlefield automation relative to manned options was formulated in terms of cost-benefit ratio and probability of success. The benefit component was found to be largely independent of whether or not the option is automated, so only system costs and relative probabilities of success were compared directly. If one assumes that a conservative policy for the employment of automation will predominate for the next several years, then robots might have lower costs and higher probabilities of success than manned systems to be employed in significant battlefield roles. Easily robots will attain lower mission costs before they will assure higher probabilities of success than manned systems.

This analysis shows that the inherent complexity in design and implementation as well as a lack of understanding of the issues of robot to operator mapping will keep robots to only the simplest, most dangerous and least critical tasks for some time to come. It also indicates that autonomous systems could be widely deployed before sophisticated teleoperated systems because of lower system costs and greater probabilities of success. However, in general the contributions by automation to battlefield operations will probably be quite limited for many years.

TMAP: An Offset System

Jerry Kirsch
Grumman Corporation

No Abstract Received

Session III Program A

Artificial Intelligence and Expert Systems I and Image Processing

Chair: Elaine Hinman, NASA/MSFC

An Expert System for Object Recovery

A. Farsaie and W. A. Venezia
Naval Surface Warfare Center
Silver Spring, Maryland 20903-5000

ABSTRACT

Expert systems offer a great deal of utility in assisting humans in a variety of domains. The explicit codification of knowledge is an illuminating process which leads to many new insights within a particular domain. A primary goal of creating an expert system is to make existing knowledge inexpensive and available. In recent years there has been a great expansion in the application of underwater Remotely Operated Vehicles (ROVs) within the Navy support community. What typically characterizes ROV operations for Navy use is a large number of standard tasks which have a great deal of variability associated with them.

An expert system is being developed using an IBM-PC to capture the essence of locating and recovery of objects from the sea floor, a daily NSWC task performed with the aid of the remotely operated underwater vehicle, TONGS. The expert system is capable of evaluating the at sea situation and dynamically modifying the TONGS search and recovery strategy to optimize operations. GOLDWORKS, an expert system development tool kit by Goldhill Co. is used in this project. This is a powerful tool which combines frames, rules and object programming into a single integrated system. Computer programs are being used to simulate sensory data from TONGS, and shipboard to the ship's navigator and TONGS operator.

This paper will summarize architecture of the expert system, and review functional performance of the TONGS utilizing the expert system.

High Level Intelligent Control of Telerobotics Systems

James McKee
Johnson Research Center
University of Alabama

and

John Wolfsburger
NASA/MSFC

ABSTRACT

This paper proposes the development of a high level robot command language for the autonomous mode of an advanced telerobotics system and a predictive display mechanism for the teleoperational mode. The authors believe that any such system will involve some mixture of these two modes, since, although artificial intelligence can facilitate significant autonomy, a system that can resort to teleoperation will always have the advantage.

The high level command language will allow humans to give the robot instructions in a very natural manner. The robot will then analyze these instructions to infer meaning so that it can translate the task into lower level executable primitives. If, however, the robot is unable to perform the task autonomously, it will switch to the teleoperational mode.

The time delay between control movement and actual robot movement has always been a problem in teleoperations. The remote operator may not actually see (via a monitor) the results of his actions for several seconds. This paper proposes a computer generated predictive display system whereby the operator can see a real-time model of the robot's environment and the delayed video picture on the monitor at the same time.

Neutral File Data Exchange Between Simulators and Robots

W. D. Engelke and D. Gilliam
University of Alabama in Huntsville

ABSTRACT

A pair of translators was developed to study the process of translating between a robot simulation system and a robot using a neutral file language. A Deneb Robotics simulator and an IBM 7535 robot were linked using the neutral file language GDL (Generic Descriptor Language). GDL describes both the geometry and logic of a simulation or a robot program and is designed to allow translation of logic and geometry between multiple kinematic simulators and multiple robots. The paper decribes the process of modeling the robot, devoloping robot software on the simulator and translating it from Deneb to GDL and finally into IBM's AML in the IBM7535 robot.

Cooperating Expert Systems

Michael Brady and Donnie R. Ford
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ABSTRACT

This paper examines the problems in applying automation to arc welding for small batch size operations, and proposes a practical adaptive control model. Two elements are identified as principal to the model: sensor fusion and expert systems. Sensor fusion provides an interpretation of the weld execution environment. The expert system accesses this interpretation, as well as a rule base, to arbitrate intelligently among competing goals, such as cost and productivity. This is accomplished using a goal reduction strategy. In order to give the model a broad base of applicability, a generic approach is taken. System development is phased in a set of steps to minimize the redundancy of effort in applying the system to new welds, weld applications, or weld processes. These steps include generic engineering, weld process engineering (e.g. MIG, GMAW, and GTAW), and application engineering. This is supported by partitioning the system into components amenable to tailoring it for the broadest possible application. These components include the process engineering laboratory, application engineering laboratory, and the field location set-up. This partitioning supports iterative development of successive weld processes and applications, and provides a functional, maintainable architecture for the system.

Space Languages--
Solving the Classic Scheduling Problem in Ada and Lisp

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The University of Alabama in Huntsville

ABSTRACT

The comparison of programming languages is best seen while evaluating similar systems. This paper will investigate the strengths and weaknesses of both languages as the scheduler is being implemented. Some features used in both languages shall be object-oriented paradigms, parallel programming, search and production heuristics, and other classical AI implementations.

This research is being supported by a grant from NASA/MSFC.

Session III Program B

Sensors and Image Processing

Chair: Lynn Craft, MICOM

A System for High Resolution 3D Mapping Using Laser Radar and Requiring No Beam Scanning Mechanisms

Paul Rademacher
Robotic Vision Systems, Inc.

ABSTRACT

The inherently high angular and range resolution capabilities associated with radar systems operating at optical frequencies are at once a blessing and a curse. Standard implementations consist of very narrow field of view optical receivers operating in conjunction with laser transmitters of even narrower illumination beamwidth. While high angular resolution is thus achieved, mechanical scanning (usually employing rotating mirrors) is required to gather data over extended fields of view. Such systems are inherently fragile. The many laser pulse transmissions necessary to cover the entire field of view increase the detectability of the system by enemy sensors. Since overall scan time is relatively long, the 3D data so gathered is inherently distorted by sensor platform or target motion.

A system concept is proposed which, through the use of a single laser transmitter and multiple optical receivers, largely eliminates the above deficiencies. Complete 3D data over a broad angular field of view and depth of field can be gathered based upon the reflections from a single transmitted laser pulse. No mechanical scanning is required and the data represents a true 3D "snapshot" of the subject scene. Covert operation is enhanced as a result of the sparse laser transmissions required. The eye safety characteristics of the system are also enhanced. The absence of delicate scanning mechanisms provides an inherently more rugged design. The 3D data acquisition rate for the system is approximately 150 times greater than that of a typical scanning system.

Proprietary coding of optical shutters in each of the multiple optical receivers permits the number of such receivers to be reduced to a very practical few. An alternative configuration of the system reduces the number of receivers required to one, at the expense of increased data acquisition time. In such a configuration, equivalent data can be gathered by transmitting and processing reflections from a small number of laser pulses--this number being equal to the number of receivers in the multiple receiver configuration. In this sense, the multiple receiver configuration is simply a parallel processing implementation of the single receiver approach. While data rate is reduced by the single receiver configuration, it still greatly exceeds that of scanning systems, and hardware complexity is also reduced significantly.

This new sensor concept has potential application to a broad range of target or scene analysis problems, both in the near and long term.

Technology Transfer: Imaging Tracker To Robotic Controller

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and

Ken Land, Harry Erwin, and Don Rhoades
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Houston, Texas 77058

ABSTRACT

The transformation of an imaging tracker to a robotic controller will be described. MDAC has developed a multimode tracker for fire and forget missile systems. The tracker "locks on" to target images within an acquisition window using multiple image tracking algorithms to provide guidance commands to missile control systems. MDAC used this basic tracker technology with the addition of a ranging algorithm based on sizing a cooperative target to perform autonomous guidance and control of a platform for an Advanced Development Project on automation and robotics. A ranging tracker is required to provide the positioning necessary for robotic control. This project was part of MDAC's Space Station Phase B effort. A simple functional demonstration of the feasibility of this approach was performed and will be described. More realistic demonstrations are under way at NASA-JSC. In particular, this modified tracker, or robotic controller, will be used to autonomously guide the Man Manuevering Unit (MMU) to targets such as disabled astronauts or tools as part of the EVA Retriever effort. It will also be used to control the orbiter's Remote Manipulator System (RMS) in autonomous approach and positioning demonstrations. These efforts will also be discussed.

Stablized Image System for Mobile Robots

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ABSTACT

The objective of this research effort is to investigate various applications of image stabilization techniques for robotic vehicles. This technology offers a low-cost means to provide a stabilized image from a moving vehicle for steering, isolation of the gunner's targeting image from weapon recoil, and other disturbances, and possible target detection and identification while moving. It will also provide for additional flexibility in a robotic vehicle vision system by allowing for scanning without mechanical turret motion and providing capability to zoom without changing the camera lenses.

An experimental system has been constructed, and a preliminary evaluation of the concept has been demonstrated This paper will present the results of this initial experimental system and then focus on future research activities. Improvements for the system include, reducing blur while compensating for high-speed motion, eliminating gyro bias, adaptation of circuit concept to color cameras, and enhancing system interface. Concepts to eliminate inertial sensors and other costly components will be pursued. The product of this research effort will be a working brassboard robotic vision system that is portable and that provides flexibility to interface with standard mobile robot sensor suites. Demonstration of this technology in realistic environments and conditions is seen as a key toward its acceptance.

Two Dimensional Convolute Integer Technology for Digital Image Processing

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TREC, Inc
An Incubator Company
A-4B Research Institute
University of Alabama in Huntsville

A demonstration of results from the application of Two Dimensional Convolute Integer Operators will be presented. The results for classical replacement point convolutions and magnification by interstitial point generation will be displayed on a PC micro-computer with a high resolution large screen (25 in) color graphics monitor.

The sensitive two dimensional frequency response of Two Dimensional Convolute Integer Operators will be seen on a number of test images, ranging from a noisy German Panzer tank image to Landsat data. Images of a noise free tank without loss of detail, images of noise bands removed, families of edge contours from low frequency (fat edges) to high frequency (thin line boundaries), Laplacians, curls, magnification and feature extraction will be presented.

Two Dimensional Convolute Integer Technology represents a family of innovative image processing operators for high-speed, two dimensional frequency-sensitive, theoretically correct classical convolutions, interstitial point generation, and missing or bad value replacement. Two Dimensional Convolute Integers Operators are mathematically equivalent to partial derivatives, a correct approach towards curl, divergence, Laplacian and gradient magnitudes and directions, and high resolution magnification.

This VAX-based PC-linked, high resolution, color image display convolution software will be described along with TREC's Digital Image Processing Environment in the Research Institute of the Johnson Research Center at the University of Alabama in Huntsville.

TREC, Inc is the first incubator company on the campus of the University of Alabama in Huntsville, associated with the Center for Applied Optics and the Center for Robotics and Artificial Intelligence.

Mr. Edwards obtained his graduate education in Physics from the State University of New York at Buffalo and came to the Marshall Space Flight Center/Space Sciences Laboratory via the National Academy of Sciences Post Doctoral Program. In 1984 he joined TREC, Inc to pursue the development of Two Dimensional Convolute Integer Technology.

Session IV Program A

Robotic Systems

Chair: Chuck Shoemaker, Human Engineering Laboratory

Development of a Hybrid Simulator for Robotic Manipulators

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ABSTRACT

The military is pursuing the use of robot manipulators and teleoperated manipulators in hostile environments. Implementation has been restricted by the rudimentary control schemes used by current manipulators. Research into improved control schemes for these manipulators has been limited by the lack of simulation capability.

The need for an adequate articulated robot simulation is great due to the problems of safety, money and work space caused by operation of a robot. An accurate simulation can assist in testing different control algorithmins, as well as different trajectory generators. Accurate models of robot arm dynamics have been identified by several groups; however, the effects of friction and drive motor dynamics have not been properly modelled in the past. These torques have important effects on errors generated by the robot.

The PUMA 560 was chosen as a case study because it represents a class of manipulators of interest to the military and because actual PUMA 560 response data was readily available. Once the proper models were installed on a digital computer and shown to be accurate by comparison to PUMA 560 responses, the decision was made to convert the model for use on a SIMSTAR Hybrid Computer. The analog model gives the control engineer greater freedom in choices of controllers to test. It also provides the capability to run realtime man-in-the-loop simulations. This model is again verified by comparison to actual robot arm motions using the same controllers.

The ability to accurately model an articulated manipulator has a significant effect on the robot community. Now, institutions restricted from controller study by the lack of an available manipulator can test state-of-the-art trajectory generators or controllers and feel confident that the simulator results will be borne out when implemented on the manipulator. Also, simulations of applications such as robotic refueling can be accomplished to determine the viability of a particular control scheme.

Omni-Con: The Self-Aligning Space Connector

H.S. Harman
Environmental Components, Inc.

and

Keith Clark
NASA/MSFC

No Abstract Received

Disconnects for Spacecraft Servicing Applications

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ABSTRACT

The goals of U.S. space programs have created a need for large, complex, long-life spacecraft. This new generation of spacecraft has created a new set of design drivers for their fluid systems. On-orbit erectability, maintain-abiility, expandability and resupply are new system requirements that in many cases cannot be achieved using existing component technologies.

Serviceable spacecraft fluid systems require disconnects to facilitate manual, remote or automated on-orbit maintenance and resupply. In response to this need, Moog has developed a unique disconnect technology that has improved performance characteristics such as pressure drop and spillage while maintain-ing configurations suitable for both manual and automated/robotic operation. This paper shall outline the state of this technology, including data genera-ted by in-house testing, in addition to industry and government evaluation.

A New Approach to Robot Kinematic Analysis

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Nashville, Tennessee 37228

ABSTRACT

Existing methods for solving robot kinematic equations can be classifed as either analytic or iterative solutions. Both classes require the derivation of the forward equations, a set of coupled transcendental equations relating end effector position and orientation to robot joint coordinates. Solution of these equations to obtain expressions for the joint coordinates as functions of the desired end effector parameters is quite difficult and only possible for robots of the wrist partitioned type. Non-wrist partitioned robot architectures must be solved using an iterative technique consisting of repetitively evaluating the forward equations for various joint values until the end effector parameters are sufficiently accurate.

A new approach for deriving robot kinematic models is being developed which is nether iterative nor analytic. This technique requires no a priori knowledge of the robot architecture, reference coordinate frame, gripper, etc. The new algorithm, given only empirical data, derives closed form equations for joint positions as functions of desired and effector position and orientation. It can also be extended to provide models of joint derivatives. The work reported herein is sponsored by a research contract from NASA and is applicable to robots for both industrial and space applications.

The joint models are derived from empirical data consisting of a set of end effector positions and orientations and the corresponding joint coordinates. This data may be obtained by evaluating the forward kinematic equations or from actual measurements of the end effector positions and orientations. The models are derived by fitting n dimensional hyper-surfaces to the data where n is the number of independent variables. When n is equal to two, this problem is reduced to the well known curve fitting problem. However, in this application there are often six independent variables. Several methods for deriving the models are described. While many standard modeling techniques exist, the dimensionality of this system complicates the problem. Several methods for deriving the models, including least squares polynomial approximation and spline techniques, are described.

This kinematic solution method has been applied to several robots with very good results. The accuracy is a function of both the number of data points used to generate the models and the order of the models. Fourth order models of the Stanford manipulator joints have mean errors on the order of 10^{-3} degrees. Results to date indicate that extremely accurate solutions can be obtained with higher order models. The partial derivatives of these models relate differential changes in end effector parameters to differential changes in the joints. The mean errors in the differential joint equations for the Stanford manipulator are approximately 0.004 degrees/mm.

A key advantage of this kinematic solution algorithm is that it provides a means of deriving the inverse kinematic equations in closed form for non-wrist partitioned robots. Using existing techniques, this class of robots requires iterative solution which is computationally more expensive. Another advantage is that no expertise is required to generate the solutions. This could reduce design costs, particularly for custom designed robots produced in low volume.

Several other advantages of this algorithm exist if the models are derived from measured data as opposed to data calculated from the forward equations. The algorithm provides a relatively simple means of compensating for link flexion resulting from heavy payloads. The error in end effector position resulting from flexion of the links is a serious problem in large manipulators and is extremely difficult to analyze analytically. Using the hyper-surface modeling technique, the payload can be included as one of the independent variables and, except that the models become n+1 dimensional, requires no further consideration.

Solutions of analytically derived kinematic equations represent the "ideal" robot, which is assumed to be manufactured with no error. It is anticipated that the algorithm being developed will be accurate enough to model the actual robot, including any manufacturing errors such as joint misalignment or error in link lengths.

Session IV Program B

Guidance, Navigation and Control

Chair: Greg Graham, USAMICOM

The DARPA Autonomous Land Vehicle: A Phase I Retrospective and a Prospective for the Future

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ABSTRACT

The Autonomous Land Vehicle Pogram (ALV)--part of the DARPA Strategic Computing program, contracted by the U.S. Army Engineer Topographic Laboratory (ETL)--combines advances in computer vision, automatic planning, sensors and advanced computer architecture to create a mobile outdoor robot that can navigate autonomously on and off roads to accomplish a high level goal. Eventual applications include partially autonomous anti-armor and reconnaissance robots for the Army, a Martian rover and more capable mobile robots for the factory.

During the first 2.5-year phase of the ALV program, road following demonstrations were performed in 1985 at speeds of 3 kph over a 1 km straight road and in 1986 at 10 kph over a 4.5 km road that had sharp curves and changing pavement types. In the 1987 demonstration, the vehicle drove at speeds up to 21 kph (average 14.5 kph) over a 4.5 km distance through varying pavement types, road widths and shadows while detecting, modeling and avoiding obstacles using a perceptual system that combined video and laser radar data to locate boundaries in three-dimensions. Also in 1987, the first vision-guided off-road experiments were performed using the Hughes vision and planning system to cover 0.6 km at speeds up to 3 kph over rolling terrain while avoiding ditches, rock outcrops, trees and obstacles as small as one metal fence post.

In Phase II, begining in early 1988 the ALV focus will be on the support of specific scientific experiments for off-road navigation instead of integrated demonstrations of military applications.

Phase I has demonstrated the feasibility of real-time autonomous navigation. It has seen the development of a test vehicle, laboratory and instrumented test areas, the dissemination of data to researchers, the development of a flexible real-time hardware and software architecture, and the development of several workable approaches to real-world, real-time vision and route and path planning. Open research issues include terrain classification and real-time segmentation techniques for images, the use of additional sensors, such as FLIR and MMW, to augment video and laser radar data, the recognition of objects, and passive ranging techniques such as motion or binocular stereo. Major engineering problems include providing enough computer power to support the real-time execution of more robust vision alogrithms and packaging the technology in low power and weight modules for use on space and military vehicles.

Development of a Man-Portable Control Unit for a Teleoperated Land Vehicle

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ABSTRACT

A man-portable control unit has been designed and fabricated to support teleoperation of a land vehicle. The basic control unit is configured to include the capabilities of mobile platform control, platform location and status display, sensor control and sensor output display, and weapons control, if so desired. When the platform is being driven to a new location, the operator must be able to control the platform through basic steering, braking and speed commands, obstacle recognition and avoidance, maneuvering in constricted space, and navigation with visual cues and simple dead-reckoning inputs from the vehicle. While the platform is on station, the human operator is to be able to perform the functions of surveillance, target recognition, target tracking, and weapons or designator control.

A fully software-driven system has been configured to meet these requirements. Video information is provided through a set of three CCTV monitors. Graphics and alphanumeric data is provided on a flat panel display. Push buttons, keypad, trackball, throttle lever, and a steering yoke accept operator input. All controls and vehicle signals are processed by an on-board micro-processor allowing an easily reconfigurable system. A video cueing system is included to allow automatic processing of the platform video for motion detection during surveillance operations.

The man-portable control unit was developed for application to the Teleoperated Mobile Antiarmor Platform (TMAP) project supported by the U.S. Army Missile Command (MICOM) . The control unit has been integrated with the MICOM vehicle system and with a vehicle system at Sandia National Labs.

Robotic Visual Servo Control for Aircraft Ground Refueling

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ABSTRACT

Advances in robotic and sensor technologies open new opportunities for applications of robotic systems. One potential application is the robotic refueling of aircraft. Three basic areas of research are required to accomplish robotic refueling better robotic control, visual servoing and force control. The Air Force Institute of Technoloy (AFIT) is conducting initial research into the design and integration of visual servoing. Visual information received from a TV camera mounted to the robot refueler's refueling boom provides the feedback data necessary for employing visual servo control techniques.

The feedback data, the refueling port's centroid and depth, is used to visually guide the robot refueler to the refueling port. To simulate the refueling operation in the laboratory, an artificial, well-defined, high contrast target-background scene is constructed; the target, a white ball, represents the refueling port and a black background represents the surrounding area. The vision-robot system (VRS), composed of a PUMA 560 robot arm and Machine Intelligence Corporation vision system, scans an area until the vision system acquires the target. Once located, the visual servo controller guides the VRS to the target. The integrated VRS uses closed loop, static and dynamic visual servo control techniques to demonstrate the capability of Using a robot equipped with vision for aircraft ground refueling.

The visual servo control techniques were implemented using the PUMA 560's VAL II programming language. Limitations in the VAL II language prevent optimal performance of the VRS, including the following; the inability to perform parallel processing and the inability to determine which robot joints are controlled. However, to date, results successfully demonstrate the VRS's ability to search for a well-defined target in a non-complex environment, and use visual servo control techniques to guide the VRS to the target.

Future research focuses on freeing the VRs from VAL II to provide better control over the robot manipulator. Also interfacing the VRS with AFIT's state-of-the-art Image Processing Laboratory is planned to allow the analysis of more complex target-background scenes found in real world environments. Finally, AFIT is starting research into closing the loop around the robot refueler application by designing better robot position and force control techniques.

Use of Mobile Robots in Responding To Radiological and Toxic Chemical Accidents

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ABSTRACT

The frequency of incidents associated with the accidental release of radiological and toxic chemical materials to the environment has become an increasing serious worldwide problem. These incidents can occur in the nuclear industry or chemical plant or facility; while radioactive materials or chemicals are being transported by air, boat, rail or by truck; at the storage/waste dump sites; and within natural gas/petroleum product pipelines. They can also develop as a result of a naturally occurring event, such as an earthquake, as noted by the release of carbon dioxide from the recent Lake Nios (The Cameroons) incident.

The emergency response team members are the individuals who are assigned to enter the vicinity of the accident to mitigate the consequences of the incident as well as assist in the evacuation of the survivors. Unfortunately, these team members can be exposed to the radioactive or toxic materials and can potentially become part of the problem. This problem can be bypassed if many of the activities assigned to the team members within the contaminated zones could be conducted by mobile robots and teleoperator controlled devices. In removing the team members from direct exposure to the harsh environments created by the released radioactive materials or toxic chemicals, many synergistic health issues and hazard situations can be eliminated.

The purpose of this presentation is to describe the roles that mobile robots have or could have played at the site of several recent accidents/incidents by assuming many of the tasks and missions that are currently conducted by the emergency response team members. Specifically this presentation will review the roles played by mobile robots at the scene of the Chernobyl-4 (USSR), Goiania (Brazil), and Washington County (PA-USA) accident/incident sites where radioactive materials and toxic chemicals were released to the atmosphere and the environment. The relative degrees of success and limitations experienced by these robots will be identified. Additional missions that the devices could have assumed at the site of these three incidents had the time and the opportunity been available will also be discussed. A synopsis of the actual and scenario concepts for the missions could then lead to expanded and justified roles that could be realized by mobile robots if they were to be employed at the site of future incidents.

The Versatool III

F.R. Skinner
Robo-Tech Systems

No Abstract Received

Reception (Marriott Ballroom

Chair: G.L. Workman, University of Alabama in Huntsville

Speaker: Joe Engelberger
Transitions Research Corporation (TRC)

Mr. Engelberger is President of Transitions Research Corporation (TRC), a young automation technology corporation in Danbury Connecticut specializing in service industry applications of robots. Mr. Engelsberger has B.S. and M.S. degrees in physics from Columbia University. He is mot widely known for helping to establish robotics into industrial markets by founding Unimation, Inc., and providing the PUMA robot family as the company's chief product. He led the company until just before its acquisition by Westinghouse Corporation and for a while primarily served as a consultant. His current interests at TRC include a thrust to broaden the applicability of robotic systems to a larger industrial as well as domestic base than that existing now.

Session V Program A

Robotic Systems

Chair: Ken Fernandez, NASA/MSFC

Speaker: J. W. Littles, Director
Science and Engineering
MSFC

Insertion with Two Coordinated Arms

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ABSTRACT

Much work has been done on the assembly of parts requiring implementation of a "peg in the hole" procedure using a single robotic manipulator guided by a force/torque transducer mounted near its end effector. In tasks such as the assembly of large structures, it may not be feasible for the object to be manipulated by a single robot. Two (or more) robots can more easily share the load and provide accurate end point guidance for parts mating.

Force/torque sensing at each robot can support three required functions: load balancing, relief of constraint forces and insertion guidance. The paper shows how information from the sensors is divided into feedback signals for the three functions in a stable manner, and gives a design example of such a system, including simulation results.

Orbital Maneuvering Vehicle (OMV) Remote Servicing Kit

Norman S. Brown
NASA/MSFC

ABSTRACT

With the design and development of the Orbital Maneuvering Vehicle (OMV) progressing toward an early 1990s initial operating capability (IOC), a new era in remote space operations will evolve. The logical progression to OMV front end kits would make available insitu satellite servicing, repair, and consummables resupply to the satellite community. Several conceptual design study efforts are defining representative kits (propellant tankers, debris recovery, module servicers); additional focus must also be placed on an efficient combination module servicer and consummables resupply kit. A remote servicer kit of this type would be designed to perform many of the early maintenance/resupply tasks in both nominal and high inclination orbits (28.5 deg and 90+ deg). The kit would have the capability to exhange Orbital Replacement Units (ORUs), exchange propellant tanks, and/or connect fluid transfer umbilicals. Necessary transportation system functions/support could be provided by interfaces with the OMV, Shuttle (STS) or Expendable Launch Vehicle (ELV).

Specific remote servicer kit designs, as well as ground and flight demonstrations of servicer technology are necessary to prepare for the potential overwhelming need. Ground test plans should adhere to the component/system/breadboard test philosophy to assure maximum capability of one-g testing. The flight demonstration(s) would most likely be a short duration, Shuttle-bay experiment to validate servicer components requiring a micro-g environment.

Inflatable End Effector Tools

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ABSTRACT

Two variations of inflatable end effector tools have been developed by Olis Engineering under a Phase II NASA SBIR contract. The primary purpose of developing this technology was to provide the capability of grasping delicate composite structural components for assembly of large structures in space. Several other benefits of this system became apparent during the course of the development effort. The inflatable end effector tools utilize controlled air pressure to inflate a bladder of two distinctive configurations to provide the grasping force. Grasping force can, therefore, be predetermined and set simply by controlling the maximum air pressure for that particular operation. Removal of the air pressure from the system deflates the bladder, releasing the item being grasped and establishing a clearance situation for repositioning of the manipulator.

Advantages of the system include simplicity, compliance, variable grasping force capability, absence of point contact loads and cost. The principal disadvantage of the simpler cylindrical probe variation is the requirement for a specified diameter hole in each item to be handled. This handling point requirement is minimal, however, and many items may be handled with this configuration without modification (i,e. tubes, pipes, etc.). The telescoping probe variation does not require a specific handling point, and is therefore most versatile, although somewhat more complex.

Both variations of inflatable end effector tools are currently being fabricated for testing and evaluation on the Proto-Flight Manipulator Arm at NASA-MSFC in Huntsville, Alabama.

Session V Program B

Manufacturing of Aerospace and Missile Systems I

Chair: Howard Race, USAMICOM

Speaker: R. E. Bowles
Chief of Mobility of Technology Planning and Management
LABCOM

Robot Assembly of Microscopic Components in Millimeter Wave Devices

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ABSTRACT

The Automation Lab of Honeywell, Inc., Armament Systems Division, has developed a robotic system to perform delicate component assembly operations which are critical to the volume production of millimeter wave transceivers. This system was developed as part of a Manufacturing Methods and Technology program which was funded by the U.S. Army Armament Research and Development Command.

The system consists of precision robotic devices which are guided by an integrated machine vision system to acquire, orient and assemble gallium arsenide beam leaded components to a duroid substrate. Assembly is accurate to within +/- .001 inch of a location defined by the microstrip artwork of the transceiver circuit. Component size is .008 inch wide by .025 inch long, including beam leads. A vacuum pick up tool was developed to manipulate the components. The tool does not touch the delicate gallium arsenide chip during the operation and does not apply over three grams of force to the component at any time. The components are held in position on the substrate by the tool while they are bonded to the substrate by an integrated laser soldering system.

Automated Millimeter Wave (MMW) Transducer Testing in a Robotic/Vision Test Cell

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ABSTRACT

This paper addresses issues associated with testing Millimeter Wave Transducers, Ka-band, in high volume production. Figure 1 shows the robotic test cell Honeywell Defense Systems Group has developed and built under a Manufacturing Methods and Technology program. The issues include (1) tuning/testing the MMW transducer by trimming the conductor pads using a transfer mechanism tied into a laser trim and vision system, for center frequency, (2) testing for RF parameters and matching the transceiver to a signal processor, and (3) interfacing all elements of the test cell through the use of robotics. The MMW transducer includes transmitter and receiver and a MMW planar antenna.

Key elements that affect testing MMW transducers in high volume production are (1) the ability to interface to the MMW transducer through the use of interconnects and testing methods because of the frequency range, Ka-band, (2) trimming the conductor pads with the laser without damaging the substrate, and (3) cycle time of different stations within the robotic test cell.

This paper will define in detail a Manufacturing Methods and Technology (MM&T) project that has addressed the above issues and transitioned the testing of MMW transducers from the lab into high volume production using robotics, lasers, and state-of-the-art test techniques.

The MM&T automated testing of MMW transducers allows the flexibility to test up to 75,000 MMW transceivers in high volume production.

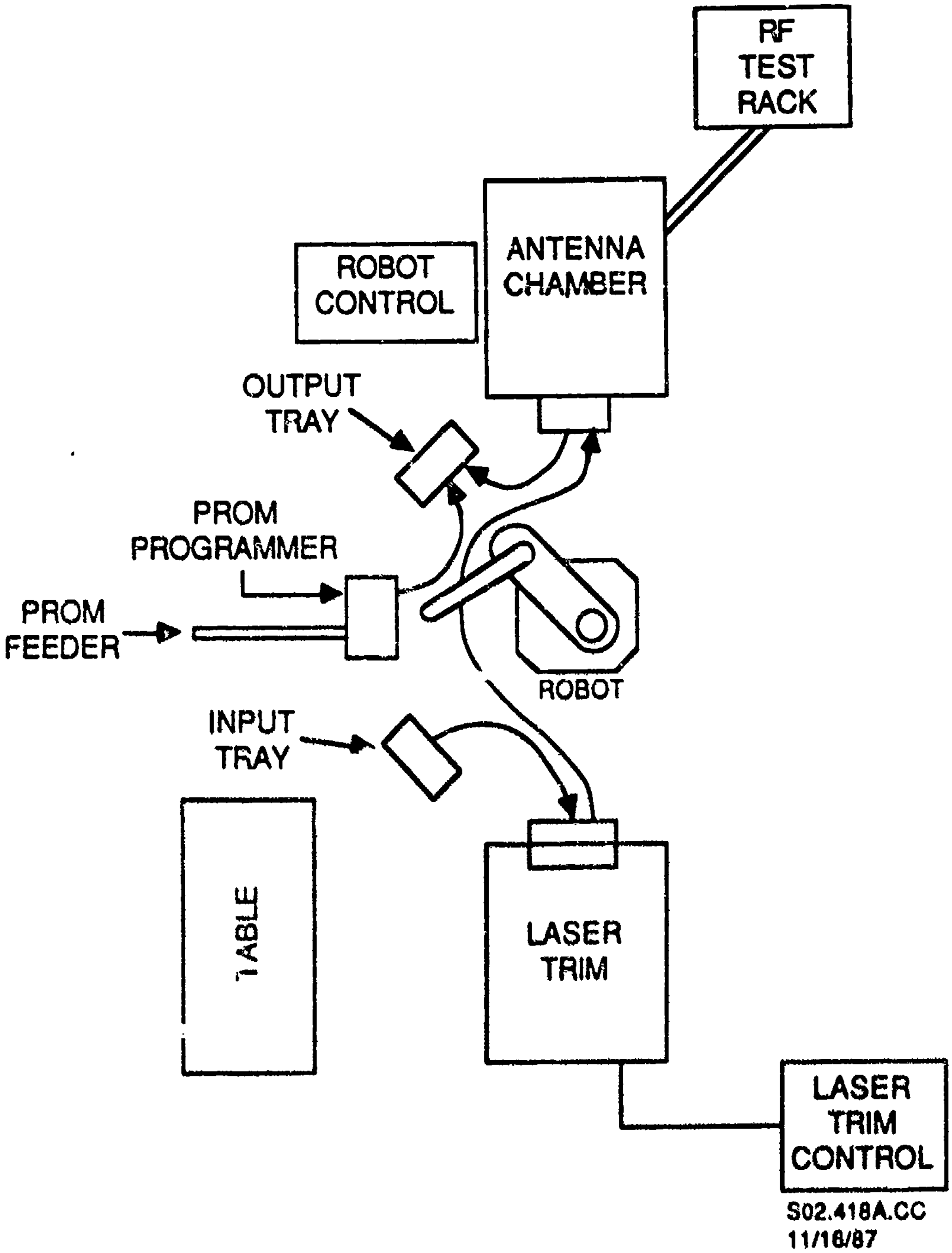

FIGURE 1.
OVERHEAD VIEW OF TUNE/TEST STATION

Development of an Integrated CAD/CAM System for Wire Harness Fabrication

J. M. Anderson and J. I. Locker
U.S. Army Missile Command

and

T. D. Morgan, L. J. Frederick and C. D. Minor
University of Alabama in Huntsville

ABSTRACT

This paper describes the development of an integrated CAD/CAM system for wire harness fabrication. The Computer Integrated Manufacturing (CIM) system is based upon a desktop AutoCad Computer Aided Design workstation and MICOM's Robotized Wire Harness Assembly System (RWHAS). The CIM system extracts and processes information from a Computer Aided wire harness Design file to generate the input file for the RWHAS Executive Controller. The data is transferred to the RWHAS CAM system via an RS-232 interface. The RWHAS then manufactures the harness.

Session VI Program A

Telerobotics

Chair: Cindy Coker, NSAS/MSFC

Testing the Feasibility of Using a Teleoperated Robot for Remote, Dexterous Operations

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ABSTRACT

This project assessed the feasibility of using a teleoperated robot to perform certain procedures associated with nuclear test facilities and space station operations. Only the space station procedure is reported here. The investigation was conducted for the Nuclear Effects Division of the U.S. Army White Sands Missile Range. It was conducted at the Robotics Laboratory of the NASA Goddard Space Flight Center. The teleoperated robot being evaluated was the Central Research Laboratories' SAMSIN Servomanipulator. This device is a seven degrees-of-freedom master/slave remote manipulator with bilateral reflected-force feedback. The ratio of slave/master reflected-force feedback could be varied so that either x:0 (none), 4:1 (weak), 2:1 (moderate) or 1:1 (realistic) amounts of reflected force were experienced by the operator. Visual feedback was by means of 3 closed-circuit television monitors.

Twenty-eight (28) novice operators were trained to execute the following simulated space station task with the SAMSIN teleoperated robot: disassemble and reassemble a space station truss node. This task was accomplished along with four (4) other nuclear-related tasks. The total of 28 novice trainees were randomly divided into four groups of 7 operators each. Each group learned to execute the tasks with SAMSIN using one of the 4 reflected-force feedback ratios. Training for each individual participant consisted of 3 sessions of about 2.5 hours duration each. The following results were obtained:

1. All operators performed all tasks at least once in the 7.5 hours.
2. Large differences in individual performance were observed among the trainees.
3. The 2:1 force ratio group showed a slight advantage on early trials.
4. After 4 trials, there was little performance difference among the 4 groups.
5. After training, the task required an average of 7.5 minutes to complete.
6. After 4 trials, both errors and completion times were reduced by half.
7. After training, non-recoverable errors were practically non-existent.

The results proved the feasibility of using a teleoperated robot with a person in the loop to perform a simulated space station-related task. Total system performance--machines, people, training and procedures--was demonstrated for this truss node operation.

ORU Guidelines for Telerobotic Compatibility

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ABSTRACT

This abstract describes work at Rockwell International's Space Transportation Systems Division to develop design guidelines for remotely maintainable Orbital Replacement Units (ORUs) for on-orbit payloads.

The quantity, complexity and cost of on-orbit payloads will increase significantly over the next few years. These payloads will need service and maintenance as their ORUs need resupply or replacement. On-orbit maintenance can be performed by an extra vehicular activity (EVA) astronaut or by telerobotic devices. However, EVA is expensive and, for repetitive tasks, is a non-productive use of human intelligence and creativity. Also, EVA may be impossible in a particular payload's orbit. Therefore, NASA and the Department of Defense are interested in concepts for ORU standardization so that payloads can be efficiently serviced by telerobotic devices. Besides relief of EVA time, other major benefits accrue to a standardization approach, including decreased design and development costs, fewer spare parts and fewer tools.

Rockwell has followed a three-step approach in developing guidelines for remotely serviceable ORUs: telerobotic concepts; ORU concepts and guidelines; and laboratory verification. During step one, a concept was developed for a telerobotic device capable of performing remote maintenance on a wide variety of ORUs. The concept included reach, degrees of freedom, speed and mass handling capability, and end effector description. During step two, specific guidelines were established for ORU compatibility with such a telerobotics device, including descriptions of fasteners; latches; fluid, electric and fiber optic connectors; racks; and packaging. During step three, hard mockups were fabricated of several types of ORUs for example, standard data processor black boxes. The boxes were then successfully changed out in the Rockwell Automation and Robotics (A/R) Facility using a seven degree of freedom master slave telerobotic device and television viewing. Future plans included further development of the ORU guidelines and then their verification by additional mockup and changeout simulation in the A/R Facility.

Ground Control of Space Based Robotic Systems

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The ability to control robotics in space is clearly an established art with the success of numerious unmanned space probes by both the U.S. and the U.S.S.R. However, these vehicles, such as the Lunakhod and Voyager, were designed to perform discrete functions, and months and years of analysis and programming were required to confidently accomplish even simple planned functions. With the advent of Space Station operations, there will be many instances where robotics will be needed to respond quickly to variable sets of environmental parameters.

A system for ground control of space robotic systems is presented and the various control paradigms and operational modes are discussed. The safety aspects, operational constraints and design considerations for robotics operation in a manned environment are discussed.

The Advanced Research Manipulator I

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No Abstract Received

Investigation of Learning Factors in the Performance of Teleoperated Tasks

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ABSTRACT

Recent work conducted at the University of Alabama in Huntsville has investigated the learning involved in the repeated performance of simple teleoperation tasks. The experiment used a simple peg-in-hole task to compare a 2 second delay operation made with the no delay mode. The results clearly show the differences in learning between the two cases and provide an indication of the learning patterns experienced.

Session VI Program A

Manufacturing of Aerospace and Military Systems II

Chair: Chip Jones

A Generalized Method for Automatic Downhand and Wirefeed Control of a Welding Robot and Positioner

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ABSTRACT

This paper describes a generalized method for controlling a six degree-of-freedom (DOF) robot and a two DOF robot and a two DOF positioner used for arc welding operations. The welding path is defined in the part reference frame, and robit/positioner joint angles of the equivalent eight DOF serial linkage are determined via an iterative solution. Three algorithms are presented: The first solution controls motion of the eight DOF mechanism such that proper torch motion is achieved while minimizing the sum-of-squares of joint displacements, The second algorithm adds two constraint equations to achieve torch control while maintaining part orientation so that welding occurs in the down hand position, and The third algorithm adds the ability to control the proper orientation of a wire feed mechanism used in gas tungsten arc (GTA) welding operations. A verification of these algorithms is given using ROBOSIM, A NASA-developed computer graphic simulation software package designed for robot systems development.

On Designing A Case-Based System for Expert Process Development

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ABSTRACT

In artificial intelligence literature, using prior experience to help solve new problem situations is termed "case-based" reasoning. Various authors have proposed using case-based reasoning for learning new concepts in mathematics, for clinical problem solving, for settling legal issues based on common law, and for interpreting and resolving common sense disputes. This paper discusses the need for such reasoning in performing process development tasks. In particular, it describes the significance of compiling case histories to capture critical process knowledge and the methods of compiling and reasoning with such histories to reduce process development time and enhance its reliability. This approach is especially useful in situations where existing processes are modified in response to frequent product changes or when processes developed for a prototype operation have to be ported to production systems.

A system to explore such ideas has been designed and is under implementation at Martin Marietta to assist process engineers and technicians in evaluating the processability and moldability of poly-isocyanurate (PIR) chemical formulations for the thermal protection of the Space Shuttle External Tank. The Process Development Advisor (PDA) aids the process engineer in (1) identifying a startup set of process parameter windows from case histories of similar chemical formulations and their moldability in test mold configurations, and (2) refining these windows by diagnosing specific process problems and suggesting adjustments for fine tuning the formulations and/or machine and model setup parameters.

The PDA is composed of six different modules: a database manager, an experimental design module, a study module, a case memory unit, a control program and a user interface.

The data base manager is used for representing and organizing numeric sensor data in the form of tables and records as they are acquired from different experimental runs of the process. The experiment design module uses all of the known process parameters and properties of interest as input and recommends an optimal experimental design matrix for evaluating the effect of the parameters on the process. It evaluates the results of the experiments for individual and interaction effects and suggests a list of critical parameters for detailed study. The study module allows detailed characterization of a process by

deriving empirical models of parameter-property relationships which are important for identifying optimum process windows. The functional relationship between the parameters and properties is an example of a model represented within the case history of a process.

The case memory unit is an episodic memory which stores case histories of past process development efforts organized in the form of MOPs (memory organization packets) and sub-MOPs. Individual events can be retrieved from case histories by approaching an appropriate contextual category of MOPs then indexing with the relevant MOP to derive information relevant to the current process development tasks. The control program is organized in the form of generalized process function schemas. Some schemas generate the appropriate context for case retrieval while others perform the necessary refinements to the retrieved models. Graphical representation of empirical models in the form of 2-D curve plots and 3-D surface plots as well as the intermediate results and final recommendations for the optimum process windows are accessible through the user interface.

Process knowledge is acquired by the system in the form of case histories. A case history is a collection of process development events represented in MOP form which consists of a context frame and a set of indices. The context frame contains information about the features (norms) that are common to all the events and sub-MOPs that are indexed under it. The indices are the characteristic features (differences) that distinguish between the events. Each MOP is a generalization of process behavior at some level of abstraction.

A case history starts with a basic set of ingredients in a chemical formulation and a corresponding set of in-process and post-process behaviors as its norms. The behaviors are modeled empirically in bottom-up fashion. To begin with, one starts with the experimental design module for the identification of process-critical variables. Then, one follows by the acquisition and organization of experimental data with the database manager. Finally, one concludes with the modeling of the relevant parameter property relationships with the study module. The study module also uses these relationships to generate optimum process windows for effective process control. Any changes that are made to the base chemical formulation to study the effect on process behavior are indexed by their differences from the norm with the MOP. For example, if the effects of a different catalyst on the process behavior have been investigated, then this event is indexed by such a difference and resulting models are stored under that index. The case memory is self-organizing in the sense that strives to minimize the search effort for the retrieval of relevant cases. It accomplishes this by identifying similarities between indices in terms of the order (first order, second order, logarithmic, etc.) of the property response models and merging them into generalized sub-MOPs, when possible. Thus, the norms of the newly created sub-MOP contain models that are applicable to a collection of events rather than to a single event. Such generalization improves the efficiency of storage as well as retrieval. Current implementation has a variable threshold on the minimum number of similar cases that would be necessary to generalize events.

The system's reasoning mechanism is guided by the control program, which consists of several process development schemas which are instantiated by a combination of input from the user and knowledge retrieved from the case memory. Typical examples of schemas are porting schemas, which contain knowledge about how to port models developed from one machine to another machine of similar make; scaling schemas, which contain information on how to scale models from a prototype operation to a production system; and characterization schemas, which contain information on how to develop a new process from conception if no relevant cases are found in the case memory.

For example, a process engineer may want to investigate the performance of a PIR polymer for use in a processing system that imparts more mixing energy than the prototype system. The PDA is given both the component description of the polymer and the distinguishing features of the target system and is asked to recommend the best startup set of process parameters that would optimize reactivity.

The PDA will first try to locate an identical case in searching through both contextual categories (MOPs) or PIR polymers and an index of mixing energy contained within. If one is found, the models under that index are transmitted to the porting schemas, which determine the optimum process window and report it to the user. If, on the other hand, the exact index is not found in the MOPs, the system reasons with the knowledge that two PIR polymers having the same polyols and catalysts but supplied with different mixing energies differ only in absolute reactivities and not in the model (first order, second order, logarithmic, etc.) employed for approximating their reactivities. It thus retrieves a model from the case history of a PIR polymer that shares the same polyols and catalysts. In this case the model is transmitted to the scaling schemas, which will recommend a minimal set of experiments (i.e., two experiments if a linear model is retrieved) to adjust the model by a scale factor. Any further refinement for optimum windows will again be handled by the porting schemas as discussed earlier.

ACKNOWLEDGEMENT

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Expert System Technology: An Avenue to an Intelligent Weld Process Control System

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ABSTRACT

This paper examines the problems in applying automation to arc welding for small batch side operations and proposes a practical adaptive control model. Two elements are identified as principal to the model: sensor fusion ana expert systems. Sensor fusion provides an interpretation of the weld execution environment. The expert system accesses this interpretation, as well as a rule base to arbitrate intelligently among competing goals, such as cost and productivity. This is accomplished using a goal reduction strategy.

In order to give the model a broad base of applicability, a generic approach is taken. System development is phased in a set of steps to minimize the redundancy of effort in applying the system to new welds, weld applications or weld processes. These steps include generic engineering, weld process engineering (e.g., MIG, GMAW, and GTAW), and application engineering. This is supported by partitioning the system into components amenable to tailoring it for the broadest possible application. These components include the process engineering laboratory application engineering laboratory, and the field location set-up. This partitioning supports iterative development of successive weld processes and applications and provides a functional, maintainable architecture for the system.

Advantages of Off-Line Programming and Simulation for Industrial Applications

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and

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No Abstract Received

Session VII Program A

Manufacturing of Aerospace and Military Systems III

Chair: J. M. Anderson, USAMICOM

A 3-D Graphical Simulation of an Automated Direct Chip Probe/Test System

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and

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ABSTRACT

This paper describes the development of a 3-D graphical simulation of MICOM's Direct Chip Probe/Test (DCP/T) system. The DCP/T system is an automated test machine that performs full dynamic electrical testing under thermal stress on integrated circuit dies. These tests are necessary to insure that the die passes military specifications. The simulation was developed using the MCAUTO robotic simulation software package and an Evans & Sutherland graphic work-station. The simulation was used to verify DCP/T mechanical and dynamical operating parameters and to assist in the design of a second generation DCP/T system.

Using a Simulation Assistant in Modeling Manufacturing Systems

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and

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ABSTRACT

Numerous simulation languages exist for modeling discrete event processes, and have now been ported to microcomputers. Graphic and animation capabilities have been added to many of these languages to assist the users build models and evaluate the simulation results. However, with all these languages and added features, the user is still plagued with learning the simulation language, which can be rather time consuming, especially if a complex system is being modeled. Furthermore, the time to construct and then to validate the simulation model is always greater than originally anticipated. One approach to minimize the time requirement is to use pre-defined macros that describe various common processes or operations in a system.

This paper presents the development of a simulation assistant for modeling discrete event manufacturing processes. A simulation assistant is defined as an interactive intelligent software tool that assists the modeler in writing a simulation program by translating the modeler's symbolic description of the problem and then automatically generating the corresponding simulation code. This paper discusses the simulation assistant. Emphasis is placed on an overview of the simulation assistant, the elements of the assistant, and the five manufacturing simulation generators. A typical manufacturing system will be modeled using the simulation assistant and the advantages and disadvantages discussed.

The simulation assistant consists of the following three elements: a simulation user interface, a library of simulation generators and an automatic code generator. The simulation assistant is written in LISP on a Symbolics 3620 LISP machine. The user interface is a LISP program that asks the user to define his problem through an interactive dialogue.

The simulation generators are a set of predefined macros or subroutines written in the GPSS simulation language that describe a generic segment of the manufacturing domain. Five manufacturing generators have been written: assembly station generator, manufacturing cell generator, inventory transfer generator, inspection generator and task generator.

The automatic code generator is a LISP program that combines the responses to the user interface with the appropriate simulation generators and then automatically generates the corresponding GPSS simulation code. The GPSS program file is then downloaded via a RS232 link from the Symbolics 3620 to the IBM PC/XT. Resident on the IBM PC is the GPSS/PC simulation language. The run parameters are then added to the GPSS file and the simulation model executed.

Algorithm for Display of Automated Nondestructive Thickness Measurements

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ABSTRACT

Automating the manufacturing processes in any environment, whether its a complex aerospace structure or a simple mechanical part, requires defining normal human judgments such that computer-based processing can perform the same function. In automating robotics installations, there is a need for defining contours which are representative of some physical feature of the object of interest. Ordinarily these operations are considered in terms of machine vision operations. The work presented here demonstrates the use of such technology for defining thickness measurements obtained through robotic ultrasonic scanning of aerospace components.

Session VII Program B

Artificial Intelligence and Expert Systems II

Chair: Bernard Schroer, University of Alabama in Huntsville

A Robotic Vehicle Global Route Planner for the 1990s

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ABSTRACT

During the 1990s, automated global route planners will take over the labor intensive and hazardous tasks vehicles are asked to accomplish. The U.S. military has already designated up to 40 vehicle missions to be accomplished by automated vehicles. In addition to the military, industry is also looking for automated vehicles to perform automated movement tasks. Thus the need has clearly been established, and new contracts for these vehicles are continually being awarded.

Vehicles designed to perform these tasks must have a global route planner that chooses the route the vehicle is to traverse. Also aboard the vehicle there must be a navigation system that confirms that the vehicle is following the desired path. While the military applications of this technology is generally off-road, the objective of this program is to gradually move this technology to the civilian arena for the guidance of automobiles and trucks on the nation's highways.

This paper will also describe the data base inputs required by the global route planner, the difficulties associated with moving from off-road to on-road operation, features that should be incorporated into the driver-machine interface/display, and the requirements on the navigation system, including a summary of potential system candidates.

A Demonstration of Retro-Traverse Using A Semi-Autonomous Land Vehicle

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ABSTRACT

A Jeep Cherokee has been modified by Sandia National Laboratoriesto allow remote control either by teleoperation or through computer driven commands (autonomy). This Jeep has been used in the development of hardware, software and application concepts for use of computer augmentation of remote controlled vehicles. As part of this development, a system has been configured which allows an operator to teleoperate the vehicle from one location (home base) to another (destination). At the completion of tele-operation, the operator can instruct the vehicle to return to the starting position. The vehicle then autonomously performs a retro-traverse, reversing the path by which it reached its destination.

During teleoperation, operator commands are given through an operator control interface consisting of a steering wheel, brake and throttle pedals, and a video display. Commands are transmitted to the vehicle and video returned from the vehicle over RF communication links. Significant way points are identified by the operator for later use by the vehicle system.

Navigation during retro-traverse utilizes dead-reckoning inputs from steering angle encoder, odometer and compass. Way points (previously identified by the operator) are linked by straight line segments. At each way point, the system determines the steering and speed commands necessary to reach the next way point in the stored path.

Retro-traverse has been demonstrated over open terrain at Sandia National Laboratories. Path following accuracy and final positional control is a function of dead-reckoning system limitations. These limitations are discussed and a system utilizing improved navigation is proposed.

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ABSTRACT

Under the sponsorship of DARPA and the U.S. Army, Martin Marietta is developing a demonstation of the avionics suite for a fully autonomous unmanned aircraft capable of seeking out and destroying hidden mobile targets deep behind enemy lines. This avionics suite has two major subsystems including perception and planning. The perception subsystem is responsible for recognizing targets and their possible hiding places during low-altitude flight using a combination of FLIR and millimeter-wave radar. The planning subsystem is responsible for maneuvering the vehicle so that as many perceived hiding places as possible can be examined in detail.

This paper focuses on the planning system and describes how it allows the vehicle to react swiftly and intelligently to percieved targets, clues, threats and obstacles in an every-changing dynamic environment. Special emphasis is placed upon how artificial intelligence technology and knowledge-based planning tecniques are being made compatible with real-time requirements.

The paper begins with a brief overview of the Smart Weapons concept of operations and its avionics suite. It then focuses in on the planning subsystem and its major components including mission management, dynamic planning, plan monitoring and plan execution. The functional design of each of these components is described in detail with emphasis on how they are being implemented in hardware and software for maximum real time performance. Finally, a detailed scenario is presented showing how the planning system responds during the fifteen seconds immediately following the discovery of a potential target.

A Knowledge Representation Scheme for a Robotic Land Vehicle Route Planner

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ABSTRACT

This paper describes knowledge representation schemes used on the Prototype Global Route Planner Project. The ultimate objective is to develop a military robotic vehicle route planner for missions covering several to tens of kilometers. The planner being developed uses a terrain database, vehicle data, and threat data coupled with trafficability, vulnerability and mission objective models.

The paper describes current efforts in vehicle mobility modelling and terrain data representation. Direct correlation between vehicle mobility characteristics and available terrain data is required for accurate mobility prediction. A combined approach using the Cross-Country Movement (CCM) model of DMA and expert derived knowledge represented in an object-based AI model is explained. Likewise, vulnerability of a potential route is assessed during the planning activity using basic threat algorithms combined with expert-derived knowledge represented in an object-based AI model. Trafficability and vulnerability considerations are weighted appropriately by the mission objective models, also derived through expert consultation.

Finally, problems encountered with current terrain databases, mobility models and representation schemes are discussed.

IRIS -- An Intelligent Robot Insertion Expert System

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ABSTRACT

Teleoperated manipulators working in an unstructured environment can perform a variety of tasks. Most maneuvers are, however, similar to the classical peg-in-the-hole problem in that the manipulator must be put in the proper postion and orientation prior to completing the task. Typical examples include inserting parts, connecting couplers and opening drawers. To maneuver the manipulator to the desirable position and orientation by teleoperation is non-trivial, and requires considerable operator training. The present work examines the possibility of exploiting AI technology to tackle this problem.

IRIS is a prototype expert system that provides a solution to the peg-in-the-hole problem. The expert system can successfully "dock" the robot with a hole in the taskboard, thereby completing the insertion process. IRIS is a rule-based, data driven, forward chaining expert system. Two sensors are required to provide input to the system: a vision system that can discern the taskboard and the hole and a ranging sensor that provides the range information. Preliminary investigation demonstrated that as long as the taskboard is placed within the work envelope in some reasonable orientation, the system can complete the mission successfully. At the time of this writing, collision avoidance is not yet implemented.

It is felt that when completed such an expert system will find application in a number of areas, especially when repetitive tasks must be conducted in an unstructured environment.

Pedagogical Issues in Developing A Man-Machine Interface for an Intelligent Tutoring System

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ABSTRACT

The use of expert and knowledge based systems have not always met with the success in the user environment as promised or expected during the development and operation in the laboratory environment. Research has shown that several specific factors have contributed to the less than expected use and performance of expert systems when placed in the user environment. A major factor is the Man-Machine Interface (MMI) associated with the delivery system. In many instances, the MMI function was considered only after the basic structure of the expert has been established and the methodology for expert operation had been demonstrated. In cases with the most reduced user acceptance are instances where the MMI function was added on after the major development effort was completed or an existing interface was expanded to meet expected user requirements. In short, the "user friendliness" promised or required for effective operation of the expert system in the user environment was not delivered.

As knowledge based systems expand in complexity and achieve extended operation in the user environment, the MMI function becomes a major issue in developing effective and usable systems. A case in point is the MMI needs associated with an effective Intelligent Tutoring System. Reported here are the results of an early research effort on major MMI issues associated with developing an Intelligent Tutoring System. The student interface or Man-Machine Interface is included as a major sub-element of the tutoring system and is considered an integral part of the system during development assessment of user needs.

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